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Investigation of an end-to-end neural architecture for image-based source term estimation

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In various critical applications, the accurate estimation of physical parameters is a necessity for ensuring public safety and effective decision-making. One such critical application where these considerations come into play is source term estimation (STE) in the context of hazardous material releases. The urgency for rapid and precise STE is accentuated by the growing risks of hazardous material releases due to accidents, acts of terrorism, or natural disasters. Quick identification of key release parameters such as the source location, timing, and environmental variables like wind speeds is essential for safeguarding public health and orchestrating effective emergency measures. Atmospheric Dispersion Simulation (ADS) models, including Gaussian models, have traditionally been employed for this purpose. While these models are efficient and simple, they require several input variables, some of which are often unknown and must be inferred from sensor data. Although many STE methodologies rely on ground-based sensors or sparse sensor networks, these are not always feasible, especially in remote or inaccessible locations. In this work, we explore an alternative approach that leverages the increasing availability of multi/hyperspectral satellite imagery for STE. Artificial neural networks (ANNs) have emerged as a promising approach to enhance STE. ANNs offer unparalleled capabilities in capturing the intricate, nonlinear dynamics inherent to the problem. Coupled with the advent of high-performance computing and GPU acceleration, ANNs have achieved rapid convergence and real-time applicability, making them a go-to solution for STE in time-sensitive and critical scenarios. However, existing ANN-based approaches for STE are designed to estimate a subset of the source term parameters such as the release rate the release rate and release time, or the source 2D coordinates, while the other parameters are assumed known. In this work, we introduce a two-stage ANN pipeline designed for estimating source term parameters from time-series hyperspectral satellite images. The first stage of the pipeline focuses on calculating the hazardous material release rate over time, subsequently generating a 3D concentration map derived from the time-series hyperspectral satellite images. The second stage utilizes the 3D concentration map to estimate the 2D source location, the release time, along with the easterly and northerly wind speeds. The effectiveness of the proposed approach is thoroughly validated using a simulated dataset.

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